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Title: MICROHOLE TECHNOLOGY PROGRESS ON BOREHOLE INSTRUMENTATION DEVELOPMENT

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MICROHOLE TECHNOLOGY - PROGRESS ON BOREHOLE INSTRUMENTATION DEVELOPMENT

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ABSTRACT

Microhole technology development is based on the premise that with advances in electronics and sensors, large conventional-diameter wells are no longer necessary for obtaining subsurface information. Furthermore, microholes offer an environment for improved subsurface measurement.

The combination of deep microholes having diameters of 1-3/8 in. at their terminal depth and 7/8-in. diameter logging tools will comprise a very low cost alternative to currently available technology for deep subsurface characterization and monitoring.

INDRODUCTION

Los Alamos National Laboratory, in collaboration with the oil industry through the US Department of Energy Natural Gas and Oil Recovery Partnership, has undertaken an integrated program to show that the cost of obtaining subsurface information can be drastically reduced through microhole technologies expressly developed to obtain that information. Collectively termed "Microhole Drilling and Technology Development," engineering efforts encompass: evaluating the feasibility of drilling deep microholes, miniaturization and testing of bottomhole coiled-tubing drilling assemblies, miniaturization of geophysical logging tools, and incorporation of emerging miniature sensor technologies in borehole seismic instrumentation packages.

Evolutionary advances in electronics and sensor technology make possible a substantial reduction in size of logging tools making conventional size boreholes no longer necessary for subsurface deployment of instrumentation. We are investigating whether microholes may offer new opportunities for improved subsurface measurements, and whether the size constraints represented by microholes may degrade the capability of current borehole measurement technologies.

Development has progressed furthest on the fabrication and evaluation of 1/2- and 7/8-in. diameter microhole seismic packages making use of miniaturized geophones and micromachined silicon accelerometers. Work has also begun on a 7/8-in. formation gamma logging tool. Competing geometric phenomena affect the overall performance of the microhole gamma tool relative to a conventional tool in larger borehole sizes.

MICROHOLE DRILLING

The Los Alamos microhole drilling system, shown in Figure 1, which in concept corresponds to much larger-sized commercial rigs, consists of a mechanical rotary bit, a hydraulically powered positive displacement motor (PDM), and a coiled-tubing drill stem. For the initial feasibility test, components suitable for drilling vertical boreholes as small as 1-3/4-in., were either procured or fabricated, and then tested as a microhole bottomhole drilling assembly in an industrial laboratory. Motor and bit performance tests demonstrated that these assemblies were suitable for coiled-tubing drilling. Penetration rates in Berea sandstone and Carthage marble exceeded 100 ft/hr (Dreesen and Cohen, 1997). Currently, Los Alamos is drilling and casing 2-3/8-in.-diameter microholes to depths of 850 ft with the equipment shown in Figure 2. The drilling to date has been in basin-and-range valley fill and volcanic tuff (Thomson et al. 1999).

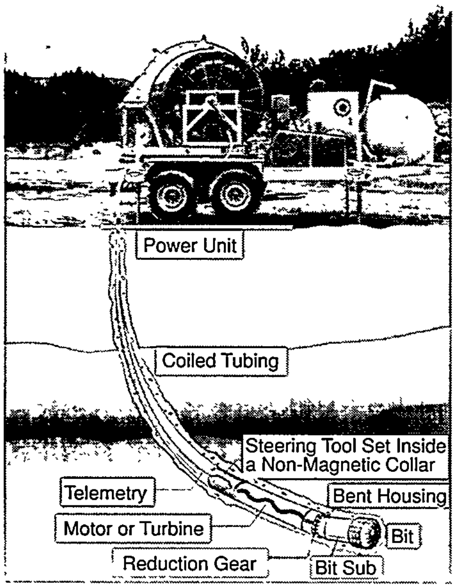

Figure 1. Los Alamos coiled-tubing drilling unit for microhole component testing, schematic of components of a bottomhole drilling assembly.

Under a separate contract to the DeepLook Collaboration (seven major oil companies and three service companies), bottomhole assemblies have been designed that will enable microholes having a 1-3/8-in. diameter to be drilled. Engineering calculations, laboratory testing, and discussions with the drilling industry have indicated that by using coiled tubing and miniaturized conventional-drilling hardware, drilling microholes to a depth of 10,000 ft should be achievable (Dreesen and Albright, 2000).

LOGGING TOOLS

Work has begun on a basic suite of 7/8-in.-diameter logging tools that is to include both spectral gamma and electrical resistivity tools, as well as a capability for surveying the trajectory of completed microholes. Furthest along in this tool development is the gamma tool.

Our studies have indicated that the gamma ray flux incident on a centralized sensor deployed in a microhole would always be greater than that for a conventional tool in an uncased, 8-1/4-in. hole. Figure 3 shows an approximate calculation for the case considering the relative gamma ray flux incident at three different energies on 1/2-in.- and 3-in.-diameter cylindrical detectors packaged in stainless steel logging tool housings.

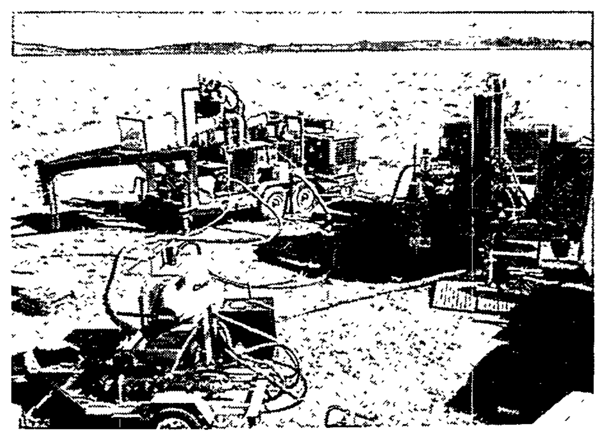

Figure 2. Drill rig (upper right), mud system (upper left) and batch cement mixer (lower left) at field site drilling emplacement microholes for microhole seismic instrumentation packages.

In this calculation only the absorption of gamma rays propagating perpendicular to the borehole axis is taken into account. Off-normal flux components will also be greater for the microhole tool because of the closer proximity of the rock above and below to the sensor in a microhole. This may cause some loss of depth resolution. The increased gamma flux incident on the microhole tool is offset by the reduced photopeak detector efficiency inherent in its smaller sensor. Figure 4 compares counts registered on a microtool detector assembly with that of a commercial logging tool over the energy range 100 to 2000 keV. In this case there is no absorbing medium between a bismuth 207 point source and the respective tool housings. Figure 5 gives the relative photopeak detector efficiency of the tools for gamma radiation at 570, 1064, and 1771 keV. The photopeak efficiency of the microtool NaI crystal is greater than 0.4 of the commercial tool up to roughly 1200 keV and then decreases rapidly. The offsetting effects of greater gamma incident flux and reduced efficiency will reduce the difference in performance between microhole and conventional tools.

In order to adequately characterize the overall performance of the microtool relative to a conventional tool, we have designed a test barrel to compare their performance over a range of borehole diameters, casings, and fluids. If the counting time to obtain comparable counting statistics in an equivalent gamma flux is excessively long for the microtool compared to the commercial tool, the mass of the NaI crystal will have to be increased in the final microtool design in order for the microtool to be of practical use.

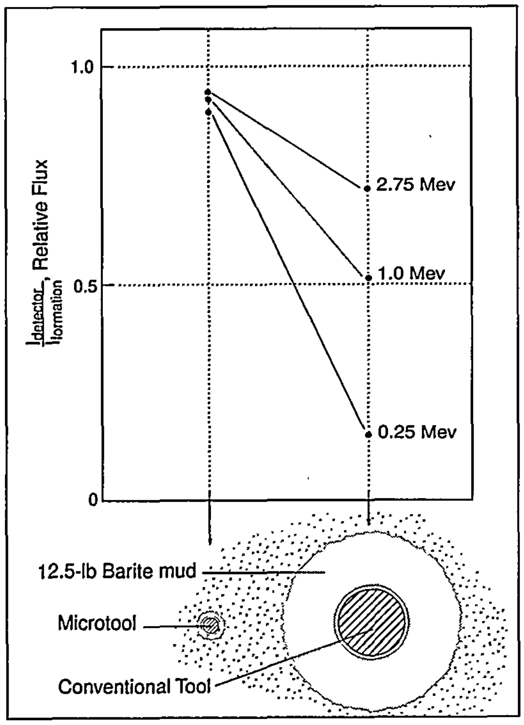

Figure 3. Relative gamma flux incident (left) on a 7/8-in.-diameter sensor package in a 1-3/8-in. microhole and (right) a commercial, 3-5/8-in. logging tool in an 8-1/4-in production well. Both tools are in open, barite-mud-filled boreholes.

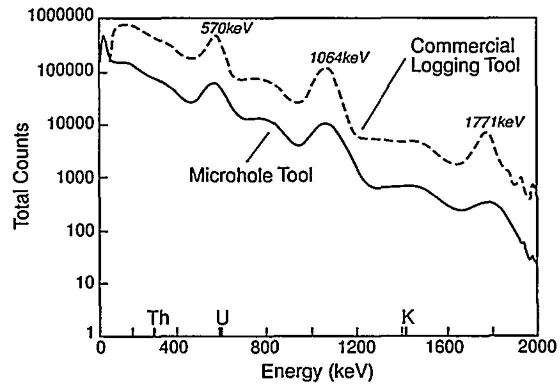

Figure 4. Comparison of total counts for 1-11/16-in. commercial and 7/8-in.-microhole gamma tools using a point Bi-207 source. The source is located 4 in. from the center of NaI crystal in each tool. The length and radius of the crystals are 6x1- and 4x1/2-in., respectively.

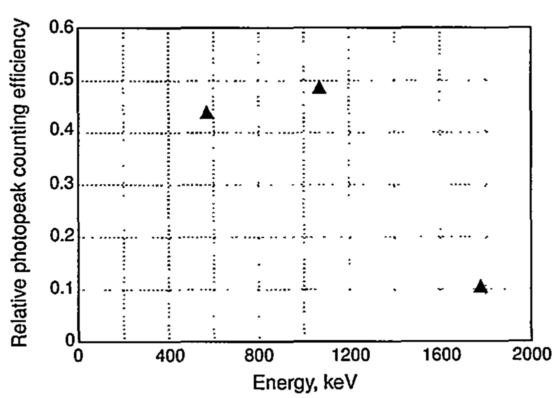

Figure 5. Net count (count minus background) photopeak efficiency of the 7/8-in. microtool relative to a 1-11/16-in. diameter commercial logging tool.

MICROHOLE SEISMIC PACKAGES

Two borehole seismic instrumentation packages have been tested and thoroughly evaluated. One contains miniaturized geophones (Albright et al. 1998); the second makes use of a micromachined accelerometer which is a member of the class of sensors called microelectromechanical systems, or simply MEMS devices (Albright et al. 1999). Both the geophones and the MEMS accelerometer exhibit a performance approaching, if not exceeding, the performance of conventional geophones.

As part of our work, Mark Products prototyped miniature (0.39-in. diameter) vertical and horizontal geophones. Los Alamos designed, fabricated, and successfully tested a wireline-deployed, 1/2-in.-diameter borehole package for testing and evaluating these geophones. The geophones were then field-tested at Amoco, Los Alamos, and Texaco borehole facilities. Though substantially reduced in size, the geophones, which are experimental prototypes, achieved a sensitivity within an order of magnitude of their full-sized counterparts.

In addition, Los Alamos, capitalizing on the Input/Output Corporation (IOC) MEMS accelerometer technology, designed, fabricated and tested two 2-level, 3-component microhole seismic arrays. A prototype

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In addition, Los Alamos, capitalizing on the Input/Output Corporation (IOC) MEMS accelerometer technology, designed, fabricated and tested two 2-level, 3-component microhole seismic arrays. A prototype 7/8-in.-diameter borehole package, which provided initial information on the performance of the MEMS sensor, was substantially redesigned to serve as an interchangeable sensor pod in a multi-pod array system. In benchtop testing, the MEMS sensor exhibits a sensitivity comparable to a commercial geophone (Gannon et al. 1999).

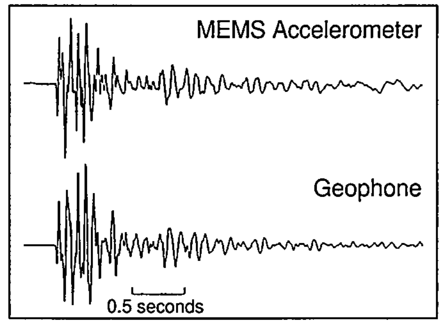
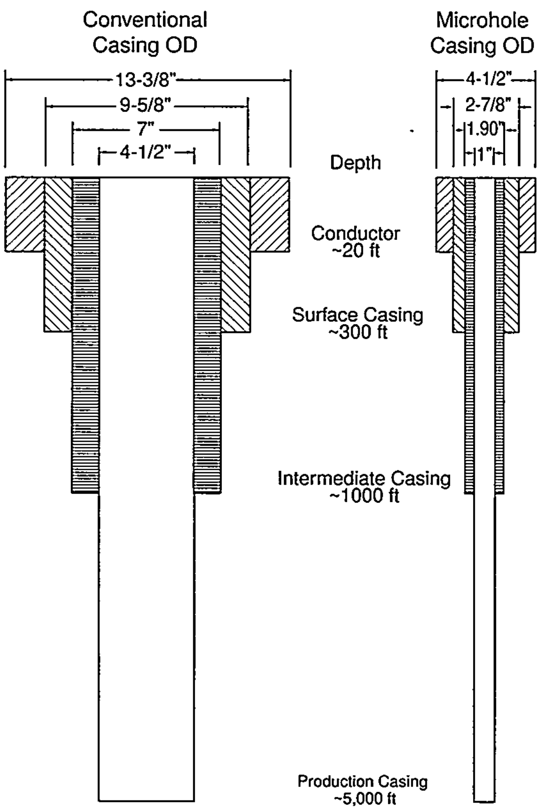


Figure 6. Near-offset signals from seismic-line experiment.

The principal objectives of the current phase of microhole seismic work are not only to incorporate MEMS sensor technology into a microhole array, but also to (1) demonstrate that the arrays can be deployed and successfully retrieved in microholes, and (2) determine the contribution that data from microhole arrays can make to seismic reflection surveying. With respect to Objective 1, four 2-3/8-in.-diameter microholes were drilled to depths of between 300 and 500 ft using the Los Alamos coiled-tubing system. These wells were cased by grouting-in 1-1/4-in., inside-diameter flush joint PVC tubing. A subcontractor to a major petroleum company collected 2D reflection data (Fig. 6) simultaneously from conventional surface geophone arrays and the two MEMS-borehole arrays using IOC System 2, data acquisition equipment. The arrays were successfully deployed and retrieved without incident. So far, field records indicate that (1) single channels of borehole data exhibited a lower, but acceptable, signal-to-noise ratio than a 9-geophone array-gather used in the reflection line, (2) array noise levels gradually declined with the depth of each array level as expeced, and (3) the horizontal-array elements recording the elastic wave showed lower amplitude motion than the verticals. ***To the best of our knowledge, this development represents the first reported use of MEMS technology for a borehole seismic array.***



Conventional			Microhole		
OD (in.)	Cost ($)	Casing Weight (lbs)	OD (in.)	Cost ($)	Casing Weight (lbs)
13-3/8	763	1,090	4-1/2	147	210
9-5/8	6,783	9,690	2-7/8	1,754	2.505
7	16,100	23,000	1.90	2,030	2,900
4-1/2	36,750	52,500	1	4,750	4,250
Total	60,396	86,280	Total	8,681	9,865

Figure 7. Comparison of microhole and conventional completions for a 5000 ft well.

ECONOMICS

For exploration and instrumentation access wells, reduction of scale to decrease costs becomes economically much more attractive when carried to microhole dimensions. Two examples of the savings due to miniaturization are shown in Figure 7, which gives dimensional, cost, and weight comparisons of a hypothetical microhole to a commonly drilled production well. The corresponding casing in each schedule is pattern-coded. The total cost of the microhole casing relative to a conventional well is 14%, and the corresponding weight reduction is 88%. Other cost reductions occur in mobilization and transportation, site preparation, drilling assemblies and mud systems. Because of scaled-down weight and material requirements for microholes, there is a potential savings in nearly every aspect of a hypothetical microdrilling system.

FUTURE

At a recent DOE Partnership Review, DOE granted funding for Los Alamos to begin preparations for drilling a 5000-ft microhole. This demonstration, in collaboration with industry, will show the capability of microhole technology for drilling a deep microhole and obtaining reservoir information.

CONCLUSIONS

In concept, components of a microdrilling system are miniaturized versions of what is for the most part familiar conventional drilling and coiled tubing technology. Consequently, to a good approximation, microhole drilling will have the same characteristics and limitations of conventional drilling technology, but will have the savings inherent in the scale reduction. Savings also accrue with the reduced material requirements associated with logging tools and equipment. As with microhole drilling equipment, small, microhole instrumentation and data gathering systems can be produced with a comparatively small investment and on a short development cycle.

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